

the common general knowledge in the relevant art on or before the priority date of the claims herein.

# **SUMMARY OF THE INVENTION**

A first aspect of the present invention provides a valve operating apparatus  
5 for an internal combustion engine including:

- a housing;
- a reciprocating piston residing wholly within the housing, the reciprocating piston driving one or more poppet valves;
- a first fluid supply path and a first fluid drain path, each path being  
10 controllable to supply or drain fluid to/from a first reciprocating piston end;
- a second fluid supply path and a second fluid drain path each path being controllable to supply or drain fluid to/from a second reciprocating piston end;

wherein said reciprocating piston, in use, is driven between a first position and a  
15 second position by controlling said fluid in said supply and drain paths, thereby operating said one or more poppet valves, characterised in that a connector passes through an aperture in said housing to connect said reciprocating piston to said one or more poppet valves, said reciprocating piston in co-operation with an internal wall of the housing forming a seal to prevent substantial egress of fluid  
20 through said aperture from the first reciprocating piston end and from the second reciprocating piston end.

In a particularly preferred embodiment, said aperture is substantially sealed by at least a portion of the external surface of said reciprocating piston to prevent egress of fluid from the housing through said aperture.

25 Preferably, said aperture is located in a side wall of said housing, and wherein an external side wall surface of said piston in conjunction with an internal side wall surface of said housing forms said seal to prevent substantial egress of fluid from the housing through said aperture.

Preferably, the longitudinal axis of said connector is substantially  
30 perpendicular to the longitudinal axis of said piston.

4a

Prior hydraulic valve operating apparatus requires a seal between the moving poppet valve stem and the hydraulic fluid supply at the point where the poppet valve stem passes through the housing. Advantageously, the present arrangement avoids such a seal. Instead, the reciprocating piston itself acts as a  
5 seal to prevent pressurised fluid from reaching the aperture from within the housing.

Internal friction in the hydraulic valve operating apparatus is lowered, as friction between the reciprocating piston and housing, already present, is not significantly increased when the reciprocating piston is used to prevent leakage of  
10 fluid through an aperture in an external wall of the housing.

I CLAIM:

1. A valve operating apparatus for an internal combustion engine including:
- a housing (2);
  - a reciprocating piston (1) residing wholly within the housing (2), the reciprocating piston (1) driving one or more poppet valves (7);
  - a first fluid supply path (3) and a first fluid drain path (5), each path being controllable to supply or drain fluid to/from a first reciprocating piston end (16);
  - a second fluid supply path (4) and a second fluid drain path (6), each path being controllable to supply or drain fluid to/from a second reciprocating piston end (17);

wherein said reciprocating piston (1), in use, is driven between a first position and a second position by controlling said fluid in said supply and drain paths (3, 4, 5, 6), thereby operating said one or more poppet valves (7), characterised in that a connector (9) passes through an aperture (14) in said housing (2) to connect said reciprocating piston (1) to said one or more poppet valves (7), said reciprocating piston (1) in co-operation with an internal wall of the housing forming a seal to prevent substantial egress of fluid through said aperture (14) from the first reciprocating piston end (16) and from the second reciprocating piston end (17).

2. A valve operating apparatus according to claim 1 characterised in that said aperture (14) is substantially sealed by at least a portion of the external surface of said reciprocating piston (1) to prevent egress of fluid from the housing (2) through said aperture (14).

3. A valve operating apparatus according to any one of the preceding claims characterised in that said aperture (14) is located in a side wall of said housing (2), and wherein an external side wall surface of said piston (1) in conjunction with an internal side wall surface of said housing forms said seal to prevent substantial egress of fluid from the housing (2) through said aperture (14).

4. A valve operating apparatus according to any one of the preceding claims characterised in that the longitudinal axis of said connector (9) is substantially perpendicular to the longitudinal axis of said piston (1).

5. A valve operating apparatus according to any one of the preceding claims characterised in that a connector rod (9) fixed to the reciprocating piston (1) connects to one or more poppet valves (7).

6. A valve operating apparatus according to any one of the preceding claims characterised in that said first reciprocating piston end (16) and said second reciprocating piston end (17) have substantially the same surface area.

10 7. A valve operating apparatus according to any one of the preceding claims characterised in that each of said first fluid supply path (3), first fluid drain path (5), second fluid supply path (4) and second fluid drain path (6) has an independently operable control valve (24), said control valve (24) operable to have a closed, partially open or open state, operation of the four said control valves (24) regulating the flow of fluid to said first and second reciprocating piston ends (16, 17), thus enabling control of the movement of the reciprocating piston (1) and hence operation of the one or more poppet valves (7).

20 8. A valve operating apparatus according to any one of the preceding claims characterised in that a reservoir of high pressure fluid (22) is in fluid connection with one or more of said fluid supply paths (3, 4, 5, 6).

25 9. A valve operating apparatus according to any one of the preceding claims characterised in that fluid in said supply and drain paths (3, 4, 5, 6) is controlled by an engine management system controller (19), said engine management system controller (19) controlling the operation of the reciprocating piston (1) and thus enabling variable lift and variable timing control of said one or more poppet valves (7).

10. A valve operating apparatus according to any one of the preceding claims characterised in that said reciprocating piston (1) may be decelerated by

controlling said fluid in said supply and drain paths (3, 4, 5, 6) to avoid crashing of said one or more poppet valves (7) onto their respective seats.

11. A valve operating apparatus according to any one of the preceding claims  
5 characterised in that said reciprocating piston (1) is biased (12) when in an inoperative state to a predetermined position, thereby biasing each said poppet valve (7) to a predetermined position and the biasing means (12) being prevented from acting on the reciprocating piston (1) when said reciprocating piston (1) is in an operative state.

12. A valve operating apparatus according to any one of the preceding claims  
10 characterised in that said reciprocating piston (1) is partially hollow, said hollow (18) providing a surface upon which vertical force may act at least at one end (16, 17) of said reciprocating piston (1).

13. A valve operating apparatus according to any one of the preceding claims  
15 characterised in that said connector (9) connecting the reciprocating piston (1) to the one or more poppet valves (7) allows each poppet valve (7) to spin about its longitudinal axis.

14. An engine including a valve operating apparatus according to any one of the preceding claims.

15. A motor vehicle including a valve operating apparatus according to any  
20 one of the preceding claims.

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☒ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**